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Chapter 1
Economic Analysis Methodology

The economic analysis of INDOT's Long Range Transportation Plan was based on INDOT's Major Corridor Investment-Benefit Analysis System (MCIBAS). MCIBAS is an economic analysis tool used by INDOT to assess the relative costs and benefits of proposed major highway corridor projects on Indiana businesses and residents. It was used in the past to analyze corridor improvements in the SR 26 and US 35 corridor and the US 31 corridor. Most recently, it was modified to develop key economic performance measures associated with the I-69 Indianapolis to Evansville project. For the present application MCIBAS was modified to consider a statewide program of projects rather than a single corridor.[1]

MCIBAS Components

MCIBAS consists of a travel demand model, a user benefit/cost analysis system, and an economic impact analysis system. Figure 1.1 shows the main components of MCIBAS and summarizes the framework of the B/C analysis used in this report. MCIBAS has the following components:

- **Indiana Statewide Traffic Demand Model (ISTDM)** – A statewide traffic network assignment model predicts the direct effects of the highway system improvement on traffic patterns, levels, and speeds, and estimates aggregate measures of systemwide vehicle-miles of travel (VMT) and vehicle-hours of travel (VHT). The ISTDM version used for the Long Range Plan economic impacts analysis was based on the model used in the I-69 Environmental Impact Statement. Unlike the I-69 study, which analyzed several alternatives, the Long Range Plan analysis included a single "build" scenario composed of many projects. Section 2 explains which projects in the Long Range Plan were included or excluded from the analysis.

- **NET_BC** – A post-processor program reads ISTDM results and translates the predicted traffic changes into estimates of the dollar value of user benefits in travel time, vehicle operating costs, and safety. Section 3 provides a summary of the user benefits estimated by NET_BC.

- **Economic Impact Analysis System (EIAS)** – A series of linked models estimates the economic impacts of the Long Range Plan. The economic impacts of the Long Range Plan are summarized in Section 4. The version of the EIAS used for the Long Range Plan analysis has three components:[2]

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[1]For a detailed description of the MCIBAS, see *Major Corridor Benefit-Investment Analysis System: Model Documentation*, by Cambridge Systematics and Bernardin, Lochmueller and Associates, 1998.

[2] For an analysis of a major corridor improvement, the EIAS would contain a fourth module that estimates direct impacts on tourist visitor-days based on changes in accessibility to tourism destinations in the study

- The ***Business Cost Savings*** module translates estimates of the dollar value of user travel time, vehicle operating cost, and safety benefits from NET_BC into direct economic impacts on business operating costs.
- The ***Business Attraction*** module translates estimates of expanded delivery and supplier market areas for businesses in Indiana into forecasts of direct business attraction beyond what would be expected due to user benefits alone.
- The **Regional Economic Models, Inc. (REMI™)** Economic Forecasting and Simulation Model[3] simulates the full economic impacts of the Long Range Plan in Indiana. REMI uses the direct economic impacts as assessed by the preceding two modules to forecast the total (direct and secondary) employment, business output, Gross State Product, and real personal income changes for 35 years.

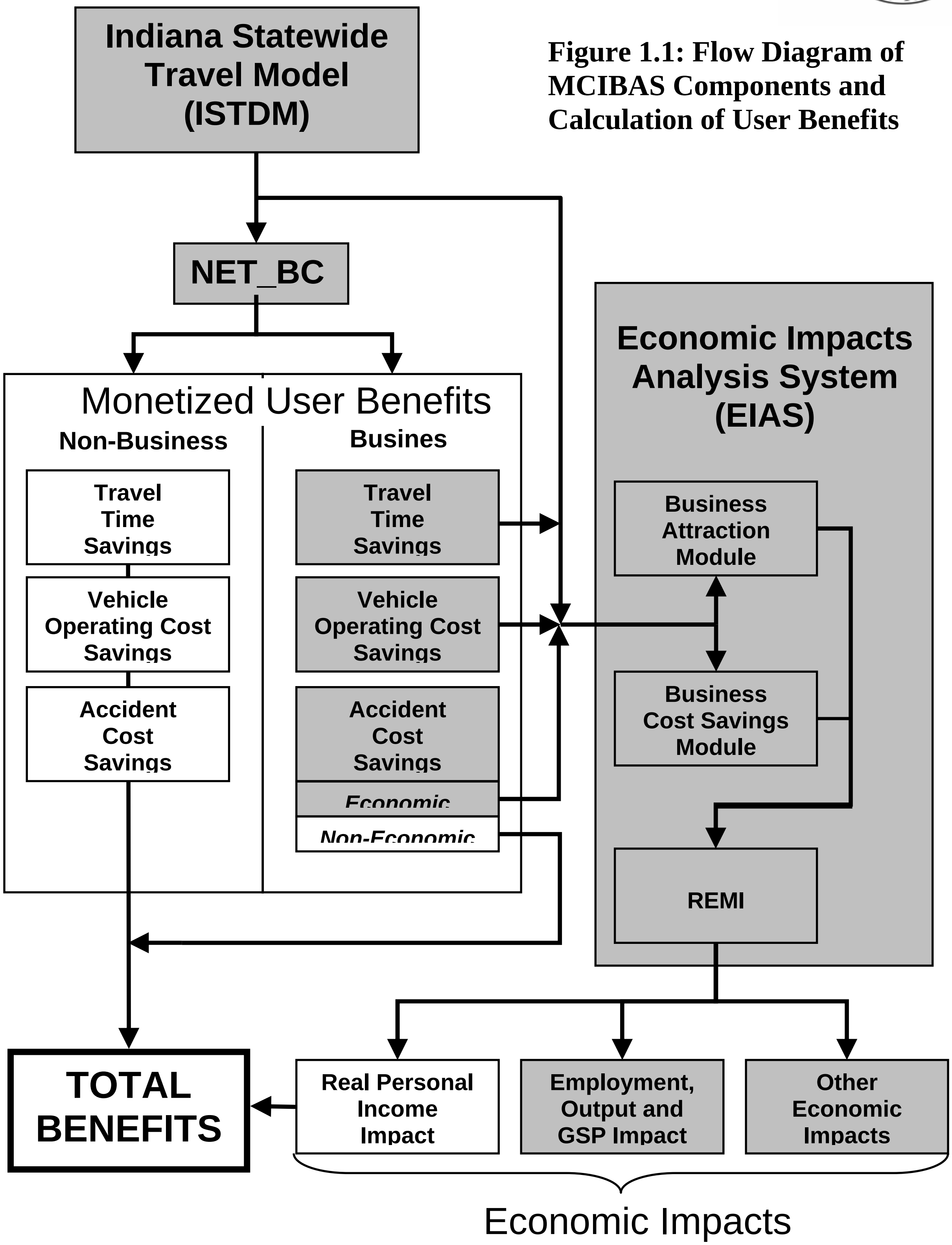
Benefit/Cost Analysis – Traditional benefit/cost analysis (B/C) for transportation projects compares the discounted value of user benefits to the discounted value of all costs (construction as well as operations and maintenance) over a specified period of time. In order to more fully account for the benefits of transportation improvements, however, B/C analyses are increasingly taking into account not only the user benefits, but also the multiplier effects of those benefits on the economy.[4] This more robust economic impact analysis generated in the EIAS formed the basis of the B/C analysis for this project.

area. The tourism module was removed from the Statewide Long Range Plan analysis for two reasons. First, highway improvements in Indiana could just as easily facilitate increased tourism travel to outside of Indiana regions as it could increase travel into the state. Second, unlike corridor-specific studies which can identify potential tourism attractions and the likelihood of a benefit, it is beyond the scope of this study to identify those types of detailed impacts.

[3]See REMI Policy Insight Users Guide, Version 3.1, for more information.

[4] Recent examples include the economic impact analysis performed for the I-69 Environmental Impact Statement in Indiana, the Cross (NY) Harbor Freight Movement Project Environmental Impact Statement, the North Country (NY) Transportation Study, and a study of the economic impacts of the Los Angeles Metropolitan Transportation Authority (LAMTA) long-range plan.

Figure 1.1: Flow Diagram of MCIBAS Components and Calculation of User Benefits



Measurement Concerns

The MCIBAS is designed to address two common problems in the evaluation of economic benefits:

- **Double Counting.** Monetary impacts can occur as changes in business output, personal incomes, or property values. These measures represent different perspectives for viewing the same basic effects of economic growth resulting from the same basic causes. Because of that relationship, care was taken to avoid "double-counting" benefits by adding together results of different levels of impact for the same class of travel. For example, a highway may save a truck driver time, leading to greater business sales, higher incomes, and increased property values along its corridor. However, it would be incorrect to add together those benefits, which all reflect the same basic effect. MCIBAS avoids that problem by focusing the measurement of economic benefits on changes in real disposable income and separately tracking the value of other factors that are not represented in this measure of economic benefits (i.e., time and safety benefits for personal travel).[5]

- **Geographic Incidence.** Also considered was the geographic incidence of the benefits. There are two considerations related to geography. First, Indiana residents and visitors make trips with an origin, a destination, or both trip ends within the state. Other trips made on Indiana highways may have both an origin and a destination outside the state. Since the benefit/cost analysis is based on costs borne primarily by Indiana taxpayers, the economic analysis emphasized benefits to travel starting or ending (or both) in Indiana rather than benefits to travelers passing through the state. Second, the benefits that accrue to Indiana businesses may be offset by business losses in adjacent states. For example, a business that relocated may be able to provide new products or services, or provide existing products and services at lower cost. For these reasons, we considered the potential business attraction impacts associated with improved market access and productivity. MCIBAS addresses this issue through an assessment of potential business attraction benefits for the State of Indiana.

Statewide versus Corridor Analysis

As its name implies, the Major Corridor Investment Benefit Analysis System (MCIBAS) was originally developed to analyze single projects in defined corridors that represent major improvements of the state highway network. However, the Long Range Plan is made up of diverse projects in rural and urban areas throughout the state, including some that add capacity to Indiana's highway system and others that focus on improvement of existing highways. It would be incorrect to compare the costs for all of the planned improvements with the benefits from only certain improvements; therefore, we removed the costs of any projects that were excluded from the travel demand model from the denominator of the B/C ratio. Section 2 includes a classification of projects by type that distinguishes between included and excluded projects.

[5] This is particularly important when performing a benefit-cost analysis.

The "included" projects were analyzed together as a group equivalent to the "build" alternative in a corridor study. In future versions of the Long Range Plan MCIBAS could incorporate the ability to evaluate a specific project or subset of projects that make up the Long Range Plan. In addition, MCIBAS has the capability to estimate benefits for the region surrounding a single capacity expansion separately from the benefits for the rest of the State of Indiana and the rest of the country. Since the Long Range Plan includes projects distributed throughout the state, the economic analysis was limited to a single region (the entire state).

Categories of Transportation Impacts

Three types of impact measures were considered for this analysis:

- **User impacts** refer to the travel time, cost, and safety improvements that are realized by passenger and freight trips on Indiana highways as a result of Long Range Plan improvements.

- **Economic impacts** are defined as benefits to the economy – i.e., the flow of dollars of income into the pockets of Indiana residents, including both travelers and non-travelers. These economic benefits can be compared to economic costs – i.e., the flow of dollars out of the pockets of Indiana residents.

- **Societal impacts** can include, in theory, all benefits and disbenefits regardless of whether or not they affect flows of dollars. They encompass both income benefits to Indiana residents and the monetary value of additional quality of life benefits that do not directly affect incomes, such as environmental and aesthetic benefits. Societal impacts also can include negative impacts, such as increased noise and pollution resulting from increased system usage.

In theory, a public agency should seek to compare total benefits to total costs. In reality, total societal impacts are seldom fully represented in benefit-cost analysis because of the lack of public agreement on the valuation of environmental and social factors. Aside from accident cost reductions, environmental and social benefits were not estimated in this analysis. Accordingly, this analysis includes user and economic impacts only.

Benefit-Cost Calculations

The benefit-cost calculation incorporates the following basic methodology and assumptions:

- **Stream of Benefits and Costs.** The transportation and economic benefits for the Long Range Plan were assumed to begin to accrue in 2003 and increase through 2028 at a rate proportional to expenditures. Since the Plan spans a period of only twenty-five years, no additional benefits associated with projects built after 2028 were calculated. However, the total benefit-cost analysis period was extended to 2032 in order to capture benefits associated with projects built toward the end of the Plan's life. This created a stream of benefits over a thirty-year period. Capital investments begin in 2003 and end in 2028. Operation and maintenance costs for the projects in the Plan were assumed to begin to accrue in 2003 and increase at a rate proportional to investments until 2028, after which they were held constant through the end of the analysis period. Figure 2.1 illustrates the assumed capital investment schedule.

- **Real Discount Rate.** Discounting streams of benefits and costs takes into account the time value of money and eliminates the expected effect of inflation as future benefits and costs are expressed in real terms (constant 2000 dollars). This rate reflects the expected return on investment, absent inflation, if the dollars invested in the infrastructure projects were invested elsewhere in the economy. For this analysis, we assumed a discount rate of 7 percent, which is the rate recommended by the Federal Office of Management and Budget for public sector benefit-cost analysis. It should be mentioned that a discount rate could have been selected that better reflects the actual costs of capital at this point in history – a rate closer to 4 percent. Had this lower discount rate been chosen, the analysis would have resulted in a significantly higher benefit-cost ratio and net present value than is reported in this document. Accordingly, the decision to utilize a 7 percent discount rate represents a conservative assumption.

- **Residual Value.** The benefit/cost analysis period includes the twenty-five years of the Long Range Plan (2003 through 2028) plus five additional years (to 2032). However, the expected useful life of many projects included in the Plan will extend well beyond 2032, especially for those investments made in the latter years of the Plan. Components of these investments (e.g., right of way) have long-term value to the State of Indiana. Accordingly, the residual values of capital investments was included in the benefit/cost analysis.

- **Operation and Maintenance Costs (O&M).** O&M costs include annual maintenance and public safety that begins when a project opens to traffic and continues throughout the economic life of the project. These costs are included in the analysis and are discounted to the same degree as the flow of benefits and capital costs. The O&M costs consist of annual maintenance cost and annual public safety cost. Annual maintenance costs increase with additional lane mileage and annual public safety costs increase with additional centerline miles.

- **Net Present Value (NPV).** The net present value of the Long Range Plan is simply the difference between the discounted present value of benefits and the discounted present value of costs. A positive NPV indicates that benefits exceed costs, and is the most reliable benefit-cost measure.

- **Benefit-Cost Ratio.** The benefit-cost ratio was calculated by dividing the total discounted benefits by total discounted costs. Essentially, a benefit-cost ration of 2.0 means that for every dollar invested (the cost), two dollars are generated (the benefit). A benefit-cost ratio above 1.0 indicates that benefits exceed costs.

Chapter 2
Long Range Plan Costs

The total value of the "added capacity" projects in the Long Range Plan is about $14.314 billion.[1] This is less than 45 percent of INDOT's total anticipated, long-range expenditures, which includes routine preservation/maintenance activities. When these preservation activities are added to the "added capacity" projects, the total investment plan has an overall price tag of about $33.2 billion. After excluding the costs of preservation/maintenance activities as well as the "committed" and "un-modeled" projects, $10.429 billion of the Plan was considered in the economic analysis (see explanation below). All costs (and benefits) are expressed in uninflated, constant 2000 dollars.

Capital Costs

The Indiana Statewide Travel Demand Model (ISTDM) estimates changes in the average daily speeds and volumes of traffic on Indiana's state jurisdictional highways (i.e., all Interstates, U.S. Routes, and State Routes) as a result of projects that increase design speed and capacity. However, the Long Range Plan is made up of diverse projects in rural and urban areas, including some that add speed and capacity to Indiana's highway system and others that emphasize maintenance and rehabilitation of existing highways.

The ISTDM is unable to calculate benefits of classes of projects that do not have a measurable impact on the utilization and travel speeds of state jurisdictional highways. Therefore, *only capacity-adding projects on the state jurisdictional highway system* were included in the economic impacts analysis. In other words, projects planned by local governments on local streets and roads are not included in this analysis. Moreover, there were five general categories of state highway projects that could not be represented in the travel model:

- **Conceptual placeholders** for proposed long-range improvements of large magnitude for which corridor alignments and/or feasibility have not yet been determined;
- **Non-highway mode projects** that are either not sufficiently defined to be modeled or are too small to have a measurable effect on the state's surface transportation system;
- **Interchange modification projects**, which involve modifications to ramps and intersections on a level of detail that is not currently represented in the statewide model;

[1] Source: Indiana Department of Transportation, Long-Range Transportation Planning Section, Division of Environment, Planning & Engineering.

- **Reconstruction and rehabilitation projects** that do not affect the capacity of a roadway significantly enough to be meaningfully represented in the statewide travel model;[2]

- **Transportation System Management (TSM) projects**, which are placeholders for traffic operational improvements primarily in urban areas where limited right-of-way essentially prevents the addition of capacity; and

- **Other miscellaneous projects**, such as the replacement of a two-way left turn lane by a median or certain new interchanges with roads not in the model network.

In addition to the projects that were withheld from the economic analysis of the Plan because they could not be represented in the travel model, certain projects designated as "committed" were also withheld since these are projects that are already being implemented. The total cost associated with excluded capital projects, including "committed" projects and those that cannot be represented in the travel demand model are provided in Table 2.1. A complete list of committed projects can be found in Appendix A.

Table 2.1. Summary of Long Range Plan Capital Investments (millions of 2000 dollars)

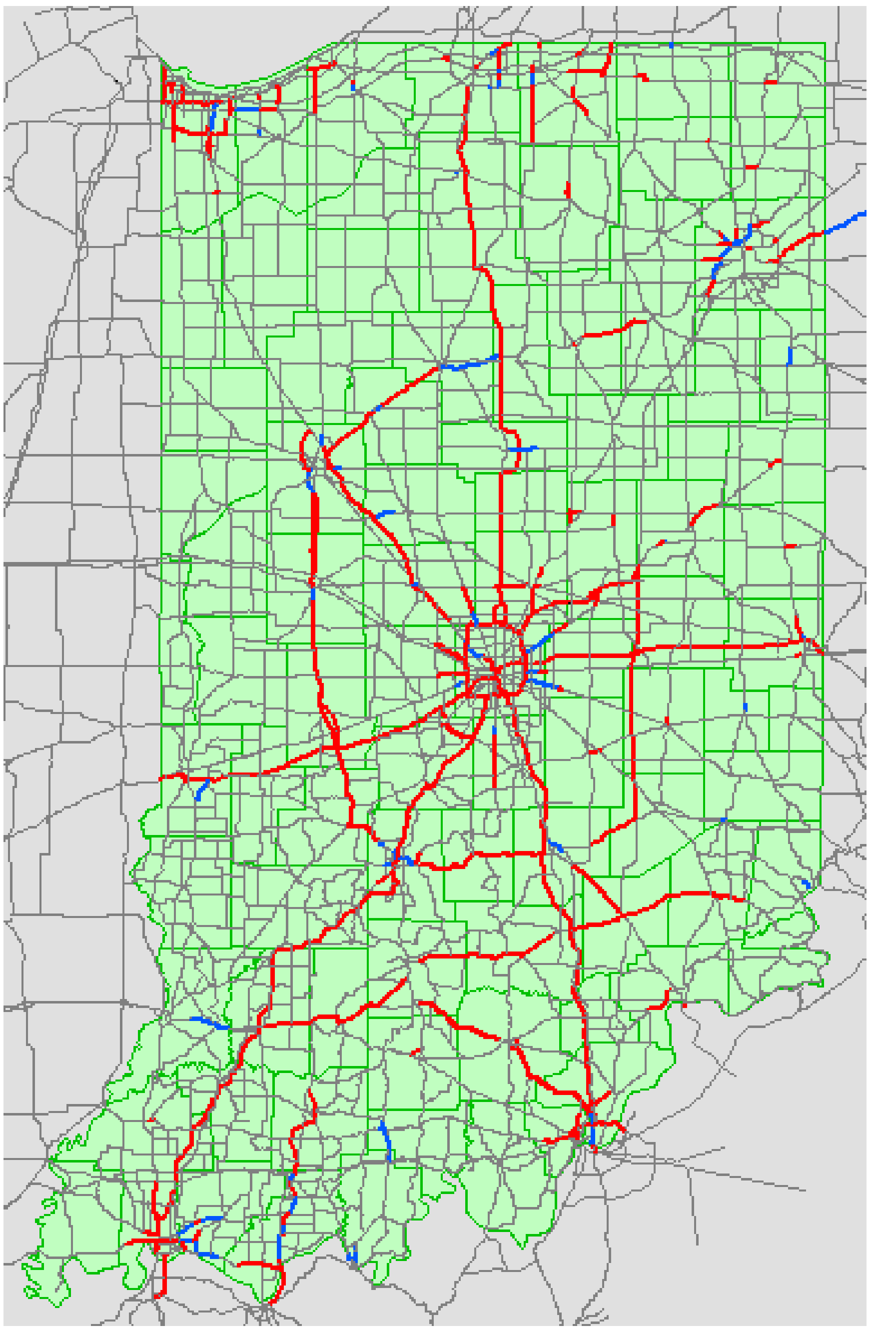
Project Category	Costs
Total Long Range Plan Costs	**$ 14,314**
Conceptual Placeholders	$ 943
Interchange Modifications	$ 1,436
Reconstruction/Rehabilitation	$ 377
TSM Projects	$ 86
Miscellaneous Un-modeled	$ 161
Subtotal of Un-modeled Projects	**$ 3,003**
Committed Projects	$ 883
Total Excluded Costs	**$ 3,886**
Total Included Costs	**$ 10,428**

Source: INDOT Long-Range Planning Section, Division of Environment, Planning & Engineering

[2] Prior to estimating the economic benefits of the LRTP, an estimation of the user benefits of reconstruction and rehabilitation projects was performed using the Highway Economic Requirements System (HERS), a long range planning tool for evaluating direct user benefits of highway system investments. The analysis estimated that reconstruction and rehabilitation projects would produce approximately $6 million in user benefits. These benefits are considerably diluted when added to the benefits of included capacity-adding projects, and therefore the incremental economic benefits of these projects are deemed as insignificant.

Figure 2.1 shows the Plan's improved and new highways in red and "committed" projects (i.e., projects completed since 2000 or in some stage of implementation) in blue.

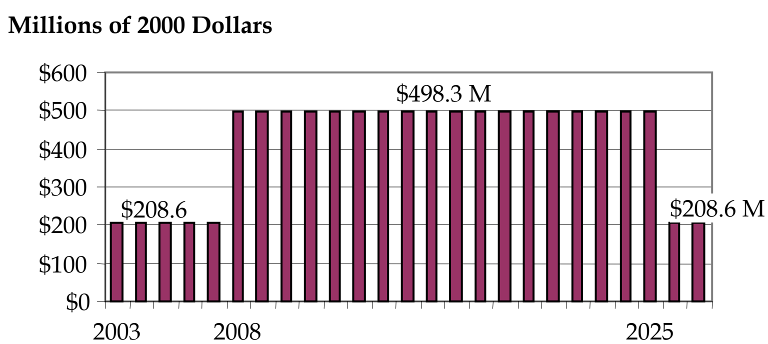
Figure 2.1: Long Range Plan Improvements Included in the Economic Impact Analysis



Timing of Long Range Capital Expenditures

The capital costs of the Long Range Plan projects are spread over the entire period of the Plan (see Figure 2.2). For the purposes of the economic analysis, it has been assumed that expenditures are constant at $498 million (or 4.78% of the total cost) for each year from 2008-2025 and at a somewhat lower rate of $209 million (or 2% of the total cost) for the years 2003-2007 and 2026-2027. The lower costs in the opening years of the Plan are due to the fact that committed projects account for a significant portion of the Plan costs in these years; whereas, the lower costs in the last years of the Plan are accounted for by the presence of the conceptual placeholder projects in these years of the Plan's implementation.

Figure 2.2: Long Range Plan Capital Expenditures



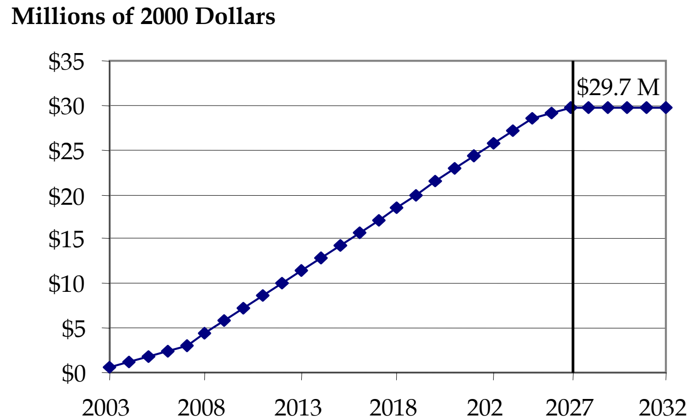
Source: INDOT, Long-Range Planning Section, Division of Environment, Planning & Engineering

Timing of Operation and Maintenance Costs

In addition to the capital costs, Long Range Plan projects resulting in additional road miles or lane miles of roadway will require an increase in the ongoing operation and maintenance (O&M) cost budget of INDOT and the Indiana State Police. Operation and maintenance costs include only the incremental cost over and above what would be incurred with or without the Long Range Plan investments.

The average annual O&M cost associated with the complete build-out of the Plan, including both the annual maintenance cost and the annual public safety cost, is estimated at $29.718 million in 2000 dollars. These costs were phased into the analysis incrementally to reflect the incremental build-out of the Plan as illustrated in Figure 2.3. O&M costs are assumed to continue at the full level for 100 years beyond the completion of the Long Range Plan (to 2128), at which time their present value has fallen to negligible levels. Costs that accrue after the end of the analysis period in 2032 are considered residual costs. These costs are included in the benefit-cost analysis because the useful life of the facilities built as part of the plan extends beyond the end of the analysis period.

Figure 2.3: Long Range Plan O&M Costs



Source: INDOT, Long-Range Planning Section, Division of Environment, Planning & Engineering

Residual Value of Investments

The benefit/cost analysis period includes the twenty-five years of the Long Range Plan (2003 through 2028) plus five additional years (to 2032). However, the expected useful life of many projects included in the Plan will extend beyond 2032, especially for those investments made in the latter years. Components of these investments (e.g. right of way) have long-term value to the State of Indiana.

To account for this value in the benefit-cost analysis, the "residual value" of the modeled plan projects were calculated and subtracted from the cumulative discounted costs. The estimation of the residual values of the various projects was based on typical highway life cycle costs for the five major capital cost components: right-of-way (infinite life), earthwork (100 years), structural costs (70 years), road base (50 years), and road surface (30 years). The discounted residual value of the $10.429 billion in improvements included in the economic analysis of Long Range Plan is $888 million at a discount rate of 7 percent.

Present Value of Long Range Plan Costs

The total discounted costs of the Long Range Plan, including capital costs, plus operation and maintenance costs, less residual value of investments, is estimated to be $3.825 billion (in constant 2000 dollars) at a 7 percent discount rate. Table 2.2 provides a summary calculation of the present value of the Long Range Plan costs.

Table 2.2. Present Value of Long Range Plan Costs Discounted at 7% (millions of 2000 dollars)

Cost Category	Present Value with 7% Discount Rate
Capital Cost (2003-2028)	$4,508
Operating and Maintenance Cost (2003-2032)	$ 149
Residual Value of Operation & Maintenance (2033-2128)	$ 56
Residual Value of Investments (beyond 2032)	($ 888)
Total Present Value of Costs	**$3,825**

Source: Bernardin, Lochmueller & Associates, Inc. and Cambridge Systematics, Inc.

Chapter 3
User Benefits

The Long Range Plan investments are expected to result in cost savings for users of the state highway system in the form of travel time savings, vehicle operating cost savings, and reductions in costs associated with accidents. In turn, these direct user benefits generate indirect benefits for Indiana's economy.

For this analysis, the NET_BC post-processor analyzed results from the Indiana Statewide Travel Demand Model (ISTDM) to generate monetary estimates of travel time savings, changes in vehicle operating costs, and reductions in costs associated with accidents. NET_BC estimated benefits in each category for four trip types:

Business Trips:

1. Truck trips,

2. Auto trips for business purposes (also called "on the clock" auto trips or "business auto" trips),

Non-Business Trips:

3. Commute trips made by auto, and

4. Auto trips for other non-business purposes.

The first two trips types are categorized as "business" trips. Reductions in travel time, safety-related costs, or vehicle operating costs for trucks or automobiles (used for business purposes) decrease business operating costs. These cost savings increase business productivity and competitiveness, which often leads to economic expansion. Business user benefits were input into the EIAS and, in turn, were used by REMI to calculate the macroeconomic effects of the Long Range Plan, including personal income and employment impacts (refer back to Figure 1.1).

The remaining two trip types are non-business, or personal, trips. User benefits associated with non-business trips do not directly impact the cost or productivity of doing business (and therefore were excluded from the economic impact analysis).[1] However, because non-business trips provide a societal benefit, the benefits of these trips were included in the benefit-cost ratio (refer back to Figure 1.1).

[1] In urban areas with highly competitive labor markets a portion of the benefits of auto commute trips may be passed on to businesses (through reduced labor costs and commuter subsidies, for example). However, since the Long Range Plan includes projects throughout Indiana, the effect of auto commute benefits on business productivity is seriously diluted and, therefore, not directly counted.

Although other types of trips, such as bicycle and pedestrian trips, might benefit from the highway improvements included in the Long Range Plan, the benefits to users of these modes are immeasurably small relative to truck and auto user benefits.

The remainder of this section presents the results of the travel time cost, vehicle operating cost, and accident cost calculations. All monetary values are presented in 2000 dollars. Appendix B contains the detailed methodology used to calculate these three categories of user benefits.

Categories of User Benefits

NET_BC calculates three categories of user benefits based on output from the travel demand model: travel time savings, vehicle operating cost savings, and accident cost reductions. Table 3.1 summarizes the user benefits associated with the Long Range Plan accruing to Indiana residents and businesses.

Table 3.1. Direct User Benefits of the Long Range Plan in 2025 Forecast Year (in millions of 2000 undiscounted dollars)

	Non-Business Trips			**Business Trips**			
Benefit Category	Auto Commute	Non-Business auto	**All Non-Business**	Business Auto	Truck	**All Business**	**All Trips**
Travel Time Savings	$421.4	$970.8	**$1,392.2**	$148.1	$374.6	**$522.7**	**$1,914.9**
Vehicle Operating Cost Savings*	($22.9)	($57.0)	**($79.9)**	($5.2)	$321.3	**$316.1**	**$236.2**
Accident Cost Savings**	$144.4	$359.7	**$504.1**	$32.7	($29.0)	**$3.7**	**$507.8**
Total Direct User Benefits	$542.9	$1,273.5	**$1,816.4**	$175.6	$666.9	**$842.5**	**$2,658.9**

Source: NET_BC. Bernardin, Lochmueller & Associates, Inc. and Cambridge Systematics, Inc.

* Negative vehicle operating cost savings represent a "disbenefit". This occurs when increased operating costs associated with faster speeds outweigh operating cost savings due to improved traffic flow.

** Includes both economic and non-economic portions of cost savings. Truck accident costs are calculated as a disbenefit, because the Plan's capacity improvements to Interstate highways and other major commerce corridors divert enough new traffic to these facilities that the added volumes create slightly higher crash rates for trucks.

Travel Time Savings Benefits

Reduction in travel time is the largest source of user benefits of the Long Range Plan. Travel time savings for business-related auto and truck trips result in direct reduction in industry operating costs, in part due to reduced labor costs and increased productivity.[2] Travel time savings were calculated by comparing the travel times for each combination of origin and destination in the ISTDM in the modeled "build" versus "no-build" conditions.[3] NET_BC then monetized values of time savings estimated by the travel demand model. For a more complete discussion of this topic, see Appendix B.

By 2025 (the forecast year for the Statewide Model), annual travel time savings benefits are estimated to total $1.9 billion in 2000 dollars for all users. Business users (including business-related auto and truck trips) are estimated to save $522.7 million in travel time costs and non-business users (including auto commute and non-business auto trips) are estimated to save $1.392 billion in 2025.

Vehicle Operating Cost Benefits

The cost of operating a vehicle is influenced by driving conditions and vehicle characteristics. Using travel speed as a proxy for driving conditions, operating costs were computed based on typical travel speeds on each link of the highway network. Costs were computed for automobiles, single-unit trucks, and heavy-duty combination trucks for six components of vehicle operating costs. Details of the assumptions are in Appendix B. All vehicle operating unit costs were converted to 2000 dollars for consistency with other user benefit values.

Several components of vehicle operating costs increase with speed, due to higher "constant speed" fuel consumption and increased wear-and-tear. On the other hand, to the extent that a project reduces speed cycle fluctuations (i.e., accelerations and decelerations) due to improved traffic flow, vehicle operating costs decrease. In the aggregate, the Plan results in lower total vehicle operating costs due to the large impact of improved traffic flow on speed cycle fluctuations for trucks. Vehicle operating costs for all vehicle classes are estimated to decrease $236.2 million in the 2025 forecast year (in 2000 dollars). Business vehicle operating costs are estimated to *decrease* $316.1 million per year and non-business costs are estimated to *increase* $79.9 million per year.

[2] For commuting trips in competitive urban labor markets, some of the commute time savings may be reflected in wages, reducing business operating costs. Since the Long Range Plan includes projects from throughout Indiana, the effect of auto commute benefits on business productivity is diluted in a statewide analysis.

[3] The calculation of travel time changes between all origins and destinations in the model allowed for the explicit treatment of travel time benefits associated with "consumer surplus". The economic principle of consumer surplus applies to longer trips in the Long Range Plan scenario that could be made within the same travel time budget due to faster speeds. See Appendix B for more information on the subject of consumer surplus.

Accident Cost Savings

Using estimates of crash rates by facility type and average daily traffic volume range, the probable number and type of accidents in the "build" and "no-build" conditions were computed. Then, average cost factors were applied specific to each of the three types of traffic crashes: fatal, injury, and property damage only. The difference between the total crash costs with and without the planned improvements represents the safety benefits of the plan.

Accident cost savings can be separated into an economic component and a non-economic component. The economic component includes direct costs such as insurance and vehicle repairs. The non-economic component encompasses intangible benefits such as reduction in pain and suffering. Only the economic component of accident cost savings for business users is used in the EIAS (see Figure 1.1). The non-economic component of accident cost savings for business users and the total (economic plus non-economic) accident cost savings for non-business users are both incorporated into the calculation of the benefit/cost ratio and net present value of the Plan.

Highway system users are estimated to save $507.8 million (in 2000 dollars) in the 2025 forecast year due to improvements in safety and the associated reductions in accident-related costs. Business users are estimated to save $3.7 million per year in accident-related costs, representing less than one percent of all accident-related benefits.

Forecast Year Direct User Benefits

Based on the discounted present value of the stream of user benefits for each year in the analysis period, the Long Range Plan will provide approximately $2.66 billion in user benefits to Indiana residents, of which 32 percent or $843 million accrue to businesses (refer back to Table 3.1).

Chapter 4
Economic Impacts

The Economic Impacts Analysis System (EIAS) is the component of MCIBAS used to estimate total economic impacts of the "added capacity projects" in the Long Range Plan in Indiana. EIAS takes into account multiplier effects, using travel efficiencies and cost savings for business trips and induced business attraction and retention benefits. To calculate the total benefits of the Long Range Plan's added capacity improvements, the primary economic benefit of the plan—an increase in personal income—was added to the user benefits of non-business trips (refer back to Figure 1.1).

It is important to remember that the economic analysis described in this report is limited only to the benefits and costs associated with *Indiana businesses and residents.* Table 4.1 shows the share of total benefits accruing to Indiana along with the computations used to derive that share.

Table 4.1. Origins and Destinations of Trips Using Indiana Highways (2025)

	A	B	$A+B=C$	$\dfrac{A+\left(\dfrac{B}{2}\right)}{C}=D$
Trip Type	**Trips with Origin AND Destination INSIDE Indiana**	**Trips with Origin OR Destination OUTSIDE Indiana**	**Total Trips with at least one origin or destination in Indiana**	**Share of Total User Benefits to Indiana**
Auto	14,094,461	1,016,966	15,111,427	96.6%
Truck	205,886	158,591	364,477	78.2%

Source: Indiana Statewide Travel Model.
Note: Excludes trips with neither an origin nor a destination in Indiana.

Economic impacts encompass only monetary flows and do not necessarily capture all aspects of benefits and quality of life. Also, economic benefits of highway improvements (as estimated by MCIBAS) differ from the travel efficiency value of user benefits. The differences are as follows:

- **Type of trips.** User benefits cover all safety, time savings, and cost savings benefits, regardless of the trip purpose. Economic benefits count only those benefits that increase the flow of money, due to reduced costs (or increased sales) for businesses and/or increased spending income available for individuals. The time savings and safety benefits for many forms of personal travel, while they are clearly benefits to users, typically do not translate into direct impacts on dollars flowing in the economy.

- **Highway usage.** User benefits accrue only to those individuals and businesses that actually use those portions of the highway network that are directly or indirectly by the Long Range Plan improvements. Economic benefits are broader in that they may accrue to any Hoosier business or resident deriving additional income from business growth attributable to the highway improvements, even a person who does not use the affected highway system. These benefits can include income from business generated by both "indirect effects" (growth of suppliers to the directly-benefiting businesses) and "induced effects" (growth of other activities from consumer spending associated with additional worker income). Thus, economic impacts do include non-user benefits.

Economic Impact Analysis System

The Economic Impacts Analysis System consists of three modules:

- The **Business Cost Savings** module translates estimates of the dollar value of user travel time, travel cost, and safety benefits from NET_BC into direct economic impacts on business operating costs.

- The **Business Attraction** module translates estimates of expanded delivery and supplier market areas for businesses in Indiana into forecasts of direct business attraction beyond what would be expected due to user benefits alone.

- The **Regional Economic Models, Inc. (REMI™) Economic Forecasting and Simulation Model** simulates the full economic impacts of the Long Range Plan in Indiana.

Business Cost Savings

Business cost savings refer to the economic effects on existing businesses that are attributable to direct travel efficiencies provided by the Long Range Plan "added capacity" improvements. Some (but not all) of the user benefits lead to direct effects on business and the economy. Reductions in travel time, safety-related costs, or vehicle operating costs for trucks or automobiles (used for business purposes) decrease business operating costs. These cost savings increase business productivity and competitiveness, which often leads to economic expansion. The value of other direct business cost impacts – including the effects of scale economies, logistics efficiencies, and enhanced product diversity – is addressed separately in the Business Attraction component of the analysis.

Business Attraction

In addition to direct cost savings for businesses, highway projects can expand the size of the market reach for businesses. The expanded market provides an opportunity for businesses to realize "economies of scale" in serving broader markets more economically. Highway system improvements can provide businesses with access to a greater variety of specialized labor skills and specialized input products, which also can help them to become more productive. (Of course, the improved highways may not only help Indiana attract outside workers and shoppers, but it also may draw residents from other states to Indiana. This effect may reduce, or in some cases, eliminate the benefits of labor pool and shopper market expansion. The analysis of secondary economic impacts, which is discussed in the next section, takes into account geographic shifts in population and employment.)

To identify potential business attraction prospects associated with the Long Range Plan, the business attraction analysis uses a quantitative screening process to identify industries that:

- Appear to be underrepresented or lagging in growth within the state relative to nearby states;
- Appear to otherwise have a compatible cost structure to perform well in Indiana; and
- Appear to be sensitive to highway market area, schedule reliability, and intermodal connection factors.

The analysis assumes that the full net increase in employment by industry will be phased in incrementally over the 25 year horizon of the Long Range Plan. It is assumed that the employment increase in Indiana will be offset partially by an employment decrease in the rest of the United States, representing business relocations from surrounding states to Indiana. Employment may also shift from one part of Indiana to another area within the state. To reduce the effect of intrastate shifts in economic activity, the change in accessibility to buyer and supplier markets (typically within a three-hour drive) was incorporated, but the change in accessibility to labor and consumer markets (typically within a 30-minute drive) was not incorporated in the analysis.[1]

Secondary Economic Impacts Using the REMI™ Economic Model

The direct economic effects described above will lead to secondary effects on the economy, in terms of increased business sales (output), employment, and income. These secondary impacts include the following:

- **Indirect economic effects**, which result from additional business sales (and associated jobs and income) generated by the additional orders for product inputs (materials, supplies, equipment, and services) required to serve the directly expanded or attracted business activities.
- **Induced economic effects**, which result from additional business sales (and associated jobs and income) generated by additional consumer spending of workers at directly or indirectly affected businesses. This spending is dispersed throughout the economy on food, clothing, shelter, recreation, education, and personal services.

[1] Accessibility to labor and consumer markets is a component of the EIAS analysis used to evaluate individual highway corridors.

- **Population effects**, which result from changes in rates of migration of households and workers caused by changes in area wages, employment opportunities, and living costs.

An economic model developed by Regional Economic Models, Inc. (REMI) was used to estimate the total (including direct, indirect, and induced) economic effects associated with changes in the flow of dollars – spending (demand), income levels, and business sales – as well as the broader impacts on regional costs, competitiveness, productivity, profitability, and population changes over time. Essentially, the direct economic effects described above are used as inputs to REMI to estimate total statewide economic effects. More detailed documentation of the REMI model is available in the REMI documentation manuals.[2]

The REMI economic model consists of four functions:

- It functions as a **forecasting tool**, which projects changes in population, employment, business sales, and profits in Indiana;

- It functions as an **input-output tool**, which accounts for the inter-industry flows of dollars and calculates the associated indirect and induced economic effects;

- It functions as an **economic competitiveness analysis tool**, which estimates how public policies and facilities change business costs in each industry, and assesses their effects on the competitive position and share of national growth captured by those areas; and

- It functions as a **population migration analysis tool**, which estimates changes in population migration in response to changes in demand for labor, wage levels, living costs, and amenities.

The REMI model combines these four functions in a singular model system, which simulates the effects of public or private projects or programs on the economy. In the Long Range Plan analysis, the study area was defined as the entire State of Indiana. The REMI model was calibrated by its developers using Indiana-specific data. For the Long Range Plan "build" alternative, the REMI model was run to develop a forecast of the economy that incorporates the benefits of the build projects. Results of the "build" alternative forecast were compared to a baseline forecast for the state, which assumes the projects are not built to estimate the impacts of the Plan.

Long Range Plan Economic Impacts

This section presents the economic impacts of the Long Range Plan analysis, based on the direct business cost savings and business attraction effects.

[2] Regional Economic Models, Inc. *REMI Policy Insight Users Guide, Version 3.1*.

Business Attraction Impacts

As described above, the Economic Impact Analysis System estimates business attraction effects in addition to business cost savings, based on improvements to market accessibility and competitive industry factors. Table 4.2 presents the statewide accessibility improvements consistent with the Long Range Plan for: employment within a three-hour drive; and improvements in drive times to airports, universities, and intermodal terminals.

Table 4.2. Percentage Change in Accessibility

Employment within a 3-Hour Drive	Airports	Universities	Intermodal
13%	3%	5%	5%

Source: Cambridge Systematics, Inc. and Bernardin, Lochmueller & Associates, Inc.

Driven by these accessibility results (in particular, the large improvements in accessibility to economic activity within a three-hour drive), Table 4.3 highlights the estimated direct business attraction results. These direct job effects are input to the REMI model to estimate full statewide economic impacts for Indiana. The business attraction model is careful to estimate only the effects for industries that tend to export their goods and services outside the State. This eliminates the potential for the double-counting that could occur if local retail and service industries were included in this calculation. Durable manufacturing (led by the fabricated metal products industry) is expected to benefit most in terms of business attraction based on the Long Range Plan highway investments. These benefits are expected to grow gradually over time, consistent with Long Range Plan investments and reach their maximum effect in 2025.

Table 4.3. Business Attraction Impact in 2025

Industry	Jobs
Durable Manufacturing	**2,711**
Nondurable Manufacturing	**938**
Trucking and Warehousing	**81**
Wholesale	**294**
Total	**4,024**

Source: Cambridge Systematics, Inc.

Employment Impacts

REMI estimates the increase in employment in 53 industry categories, roughly consistent with the 2-digit Standard Industrial Classification (SIC) codes. Table 4.4 shows the employment impacts for the Long

Range Plan, grouped into ten industry sectors to show variations in employment impacts across industries over time. Impacts are shown in 2013 (ten years in the future), 2023 (twenty years from now), 2028 (the final year of investment), and 2033 (five years after last Long Range Plan investment, and thirty years in the future). In addition to jobs that are forecasted to be created in the "no-build" scenario, the Long Range Plan is estimated to add 15,000 jobs to Indiana's economy by 2028.

Table 4.4. Additional Jobs Due to the Long Range Plan Compared to the No-Build Condition, by Industry Sector over Time

	Year			
Industry	**2013**	**2023**	**2028**	**2033**
Durable Manufacturing	1,600	2,650	3,180	3,350
Non-Durable Manufacturing	620	1,000	1,180	1,270
Mining	0	0	0	0
Construction	840	770	760	930
Transportation and Public Utilities	890	870	850	1,040
Finance, Insurance, and Real Estate	570	580	590	690
Retail Trade	2,890	2,900	2,880	3,370
Wholesale Trade	480	560	600	670
Services	2,470	3,010	3,390	4,130
Agriculture, Forestry, and Fishery Services	190	270	310	400
Total Private Sector, Non-Farm Employment Impact	**10,550**	**12,610**	**13,740**	**15,850**
Government and Farm Employment Impact	830	1,230	1,310	1,480
Total Employment Impact	**11,380**	**13,840**	**15,050**	**17,330**

Source: REMI

As the magnitudes of the user benefits increase between 2003 and 2028, employment impacts also increase. However, because this analysis is limited to the Long Range Plan investments that end in 2028, the employment impacts attributable to this Plan show a decrease between 2028 and 2033. User benefits grow until 2028, but then level off after the last improvements are made to Indiana's transportation system. After 2028 inflationary forces such as price and wage increases overcome the static user benefits, dampening the employment impacts in durable manufacturing, construction, retail trade, and wholesale trade. In reality, INDOT will almost certainly continue making transportation improvements after 2028 and employment impacts will continue to grow.

Other Long Range Plan Impacts

REMI provided estimates of gross state product, real personal income, and business output impacts. Because the economic impacts presented in this section were all derived from the same user benefits, only real personal income was added to non-business user benefits to calculate the numerator of the benefit/cost ratio for the Long Range Plan (see Figure 1.1). The other three economic impacts are provided to present several dimensions of economic benefits, but are not applicable to the benefit/cost analysis, *per se*. Table 4.5 summarizes the economic impacts of the Long Range Plan in 2013, 2023, 2028, and 2033. Impacts are estimated to increase in magnitude between 2003 and 2028 as more and more of the Long Range Plan investments are implemented. After 2028, impacts are shown as growing at a slower rate as inflationary pressures overcome the static user benefits of the Long Range Plan.

Table 4.5. Summary of Economic Impacts of the Long Range Plan over Time

	Year			
Economic Impact	**2013**	**2023**	**2028**	**2033**
Real Personal Income (Millions of 2000 dollars)	$653.8	$928.7	$1,079.5	$1,427.9
Gross State Product (Millions of 2000 dollars)	$1,033.3	$1,724.6	$2,155.8	$2,665.7
Output (Millions of 2000 dollars)	$1,832.1	$3,129.9	$3,955.7	$4,884.6
Employment (jobs)	11,380	13,840	15,050	17,330

Source: REMI
Note: These impact categories are different ways of measuring the same effects and are not additive.

Net Present Value of Long Range Plan Benefits

In order to calculate the benefit/cost ratio and net present value of the Long Range Plan, the various benefits streams were discounted to constant 2000 dollars and added together. Although previous sections cited numerous benefits of the Long Range Plan, not all of these benefits are expressed in monetary terms and not all of them are additive. For this analysis, the components of benefits used in the benefit/cost ratio calculation are:

- Travel time savings for non-business users;
- Vehicle operating cost savings for non-business users;
- Economic and non-economic components of accident cost reductions for non-business users plus, the non-economic component of accident cost reductions for business users; and
- Real personal income impacts.

MCIBAS estimated each of these benefits for the 2025 forecast year. Growth rates in travel demand and annual expenditures in the Long Range Plan were calculated to estimate annual benefits and costs for each year in the analysis period. The annual streams for the four components of benefits were then discounted and summed to compute their present values.

Discount Rate

Benefit/cost analysis discounts monetary values to reflect the time value of money when comparing cost and benefit streams that occur over a period of time. The discount rate represents the "opportunity cost" of taking dollars out of the private economy, where it might otherwise achieve a particular return on investment. The discount rate reflects assumptions about that alternative return on investment.

The benefit and cost streams were discounted at the same rate. Standard practice calls for the selection of a discount rate approximately equal to the "cost of capital" for a public investment without any allowance for inflation. There is no need to account for inflation since both benefits and costs are computed in constant dollars.

The choice of a discount rate can have a major impact on the outcome of the analysis. Expenditures on projects in the Long Range Plan occur within the time frame of the 25-year plan, from 2003 to 2028. In contrast, the benefits associated with projects in the Long Range Plan accumulate over the entire useful life of the projects, which will extend beyond 2028. Therefore, benefits are discounted more deeply than the costs. The higher the discount rate, the more the benefits are penalized as compared to the costs.

At the time of this analysis, the actual cost of capital for long-term public investments (excluding an allowance for inflation) was about 3.2 percent.[3] From a historical perspective, this is a very low rate. Notwithstanding the current low cost of capital, a value of 7 percent was selected for this analysis in accordance with the recommendation of the Federal Office of Management and Budget[4]. This choice

[3] Office of Management and Budget, Executive Office of the President, January 2003. *Discount Rates for Cost-Effectiveness, Lease Purchase, and Related Analyses.* OMB Circular Number A-94, Appendix C.

[4] Ibid.

may be understood as conservative. If a lower discount rate were chosen, the resulting net present value and benefit/cost ratio would be significantly higher.

Present Value Calculation

The total present value of the four benefits categories was estimated to be $17.6 billion in 2000 dollars, assuming a seven percent discount rate. Table 4.6 contains a summary calculation of the present value of the benefits of the Long Range Plan.

Table 4.6. Present Value of Long Range Plan Benefits Using a 7% Discount Rate (millions of 2000 dollars)

Benefit Category	Present Value with 7% Discount Rate
Travel time savings for non-business users	$7,000
Vehicle operating costs for non-business users	($400)
Accident cost savings for non-business users (economic and non-economic components) plus accident cost savings for business users (non-economic component only)	$2,500
Real personal income	$8,500
Total Present Value of Benefits	**$17,600**

Source: Cambridge Systematics, Inc.

Chapter 5
Long Range Plan Benefit / Cost Ratio and Net Present Value

Assuming a 7 percent discount rate, the Long Range Plan has benefit/cost ratio of 4.6 and a net present value of $13.8 billion in 2000 dollars (see Table 5.1). A benefit-cost ratio above 1.0 indicates that benefits exceed cost and represents the lowest value that should be considered for a transportation investment if no other non-monetized factors are to be considered.

Table 5.1. Benefit/Cost Ratio and Net Present Value of the Long Range Plan in millions of 2000 dollars

	7% Discount Rate
Present Value of Benefits	$17,600
Present Value of Costs	$3,800
Net Present Value	$13,800
Benefit / Cost Ratio	4.6

Conclusions

There is a considerable amount of uncertainty reflected in any benefit-cost analysis. Costs and benefits can change, and the choice of discount rate can have a significant impact on the analysis outcome. Typically, strong projects have a high enough benefit/cost ratio so that even if less favorable assumptions are used, there is still a benefit that exceeds the cost.

The results discussed above provide compelling evidence that the State of Indiana's Long Range Transportation Plan represents a strong investment. Moreover, given the strength of these numbers, it is highly unlikely that less favorable assumptions would change this conclusion.

Appendix A: List of Committed Projects

Route	County	Project Type	Project Length	Description
I-65	MARION	Added Travel Lanes	5.28	Kessler Blvd to 0.5 mile north of I-465 (West Leg)
I-65	CLARK	Added Travel Lanes	1.75	L&I RR (south of Stansifer Ave) to 0.76 mile north of Eastern Blvd
I-65	CLARK	Added Travel Lanes	2.04	0.76 mile north of Eastern Blvd to 1.07 miles north of SR 131
I-65	CLARK	Added Travel Lanes	1.84	1.07 miles north of SR 131 to 1.06 miles north of I-265
I-65	CLARK	Added Travel Lanes	1.00	1.06 miles north of I-265 to 1.0 mile north of SR 60
I-69	ALLEN	Added Travel Lanes	4.81	0.48 mile south of Coldwater Rd to 0.86 mile north of SR 1
I-69	ALLEN	Added Travel Lanes	6.22	2.16 km south of north jct with US 24 to 1.0 km south of Leesburg Rd
I-69	ALLEN	Added Travel Lanes	4.82	1.0 km south of Leesburg Rd to 0.48 km south of Coldwater Rd
I-69	ALLEN	Added Travel Lanes	4.98	1.73 mi N of interchange with SR 14 to interchange with Coldwater Rd
SR 1	FAYETTE	Added Travel Lanes	1.35	17th St to 30th St in Connersville
SR 135	JOHNSON	Added Travel Lanes	1.90	CR 700N (Stones Crossing Rd) to Smith Valley Rd
SR 145	PERRY	New Road Construction	6.10	I-64 to 3.5 miles north of Perry / Crawford County Line (Segment 1)
SR 145	CRAWFORD	New Road Construction	6.00	3.5 miles N of Perry / Crawford County Line to SR 145, 1.9 miles N of SR 64 (Seg.
SR 149	PORTER	New Road Construction	1.80	US 30 to SR 130 (CN phase only)
SR 17	MARSHALL	Added Travel Lanes	0.93	0.73 mile south of US 30 to 0.2 mile north of US 30 in Plymouth
SR 19	ELKHART	Added Travel Lanes	2.20	0.4 mile N of US 20 (Melwood Dr) to 2.6 miles N of US 20 (Lusher Ave)(Phase I)
SR 229	FRANKLIN	Added Travel Lanes	0.60	I-74 to Six Pine Rd in Batesville
SR 23	ST. JOSEPH	Added Travel Lanes	1.18	Gumwood Rd to Fir Rd
SR 23	ST. JOSEPH	Added Travel Lanes	0.68	2.4 miles north of I-80/90 (Fir Rd) to Brick Rd
SR 237	PERRY	New Road Construction	5.50	SR 66 / SR 237 Lincoln Trail Bridge to SR 37
SR 26	TIPPECANOE	Added Travel Lanes	1.50	I-65 to 0.3 mile east of CR 550E
SR 28	CLINTON	New Road Construction	4.70	I-65 to 3.23 miles west of SR 39
SR 3	ALLEN	Added Travel Lanes	0.83	At I-69 (2 added lanes from Ley Rd to 1500' north of Washington Center Rd)

SR 32	BOONE	Added Travel Lanes	1.52	1.0 mile west of I-65 to 0.52 mile east of I-65
SR 32	DELAWARE	Added Travel Lanes	0.56	0.1 mile west of Nebo Rd to 0.4 mile east of Nebo Rd
SR 331	ST. JOSEPH	New Road Construction	1.88	US 20 to Just South of 12th St.
SR 331	ST. JOSEPH	New Road Construction	0.50	Jefferson Blvd to McKinley Ave
SR 43	TIPPECANOE	Added Travel Lanes	0.96	0.2 mile north of I-65 to 1.16 miles north of I-65
SR 43	TIPPECANOE	Added Travel Lanes	0.77	1.16 miles north of I-65 to 1.93 miles north of I-65
SR 431	HAMILTON	Added Travel Lanes	0.61	0.61 mi S of interchange with US 31 to interchange
SR 45	MONROE	Added Travel Lanes	0.38	0.1 mile east of SR 46 to 0.1 mile east of Pete Ellis Dr
SR 46	MONROE	Added Travel Lanes	3.10	Walnut St to 3rd St in Bloomington (SR 45/46 Bypass)
SR 46	MONROE	Added Travel Lanes	0.80	Main St to 400 feet east of CSX RR in Ellettsville
SR 46	MONROE	New Road Construction	1.50	West UAB of Bloomington (Smith Rd) to 0.5 mile west of SR 37
SR 48	MONROE	Added Travel Lanes	1.90	2.5 miles west of SR 37 to 0.6 mile west of SR 37
SR 48	DEARBORN	New Road Construction	1.83	Wilson Creek Rd to US 50
SR 56	GIBSON	New Road Construction	0.16	2nd and Mill St to 1st St in Hazleton
SR 62	WARRICK	Added Travel Lanes	5.35	I-164 to the West Corp Line of Chandler
SR 62	WARRICK	Added Travel Lanes	3.79	6th St in Chandler to 0.15 mile east of West UAB of Boonville (Phase II)
SR 62	WARRICK	Added Travel Lanes	0.36	0.15 mile east of West UAB of Boonville to Locust St (Phase III)
SR 641	VIGO	New Road Construction	2.73	US 41 to 0.25 mile north of existing Feree Rd
SR 641	VIGO	New Road Construction	3.23	0.25 mile north of existing Feree Rd to I-70
SR 66	PERRY	Added Travel Lanes	1.50	1.8 miles east of east jct with SR 37 to 0.1 mile west of west jct with SR 237
SR 66	WARRICK	Added Travel Lanes	3.40	I-164 to just east of SR 261 (Phase I)
SR 66	WARRICK	Added Travel Lanes	3.12	Just east of SR 261 to SR 662 (Phase II)
SR 66	WARRICK	Added Travel Lanes	4.40	SR 662 to Yankeetown Rd (Phase III)
SR 662	VANDERBURGH	Added Travel Lanes	1.27	Just east of I-164 to 0.12 mile east of Ellerbusch Rd
SR 9	LAGRANGE	Added Travel Lanes	0.70	0.3 mile south of I-80/90 to Indiana / Michigan State Line
US 231	SPENCER	New Road Construction	4.73	SR 70 to CR 1250N (Phase II)
US 231	SPENCER	New Road Construction	3.81	CR 1250N to SR 162 (Phase III)
US 231	SPENCER	New Road Construction	1.61	SR 62 to CR 2050N (Phase V)

US 231	SPENCER	New Road Construction	4.95	0.87 mile north of the north jct with SR 66 to 1.15 miles south of SR 70 (Phase I
US 231	MONTGOMERY	Added Travel Lanes	0.47	1.36 mile south of south jct with SR 32 to Crawfordsville South UAB
US 231	MONTGOMERY	Added Travel Lanes	1.42	Crawfordsville South UAB to 0.3 mile south of US 136 at Jefferson St
US 231	SPENCER	New Road Construction	8.22	Natcher Bridge & Approaches
US 231	SPENCER	New Road Construction	1.17	Southern portion of Dale by-pass
US 24		Added Travel Lanes	69.00	Ohio portion of upgrade of US 24 "Fort to Port" corridor
US 27	WAYNE	Added Travel Lanes	0.30	0.9 mile north of I-70 (Arba Pike) to 1.21 miles north of I-70 (Tingler Rd)
US 27	ADAMS	Added Travel Lanes	4.82	SR 124 to Relocated US 33
US 31	BARTHOLOMEW	Added Travel Lanes	3.94	CR 50N, 1.48 mile south of old SR 46 to 2.46 mile north of old SR 46
US 33	ALLEN	Added Travel Lanes	1.70	US 30 to Cook Rd
US 35	HOWARD	Added Travel Lanes	6.20	Goyer Rd to Wildcat Creek, 0.5 mile east of US 31 to 6.7 miles east of US 31
US 35	LA PORTE	Added Travel Lanes	1.15	0.45 mile northwest of south jct with SR 39 to north jct with SR 39
US 36	MARION	Added Travel Lanes	2.03	0.18 mile west of I-465 to 0.22 mile east of Post Rd (Phase II)
US 36	MARION	Added Travel Lanes	3.37	0.22 mile east of Post Rd to 0.2 mile east of Oaklandon Rd (Phase I)
US 36	MARION	Added Travel Lanes	2.10	0.2 mile east of Oaklandon Rd to 0.18 mile east of CR 750N (Phase III)
US 40	MARION	Added Travel Lanes	2.20	Raceway Rd to Research Dr
US 40	MARION	Added Travel Lanes	2.36	Franklin Rd to Grassy Creek (1.57 miles west of Marion/Hancock County Line)
US 421	HAMILTON	Added Travel Lanes	1.05	0.16 mile south of I-465 to 0.89 mile north of I-465 (Phase 1)
US 421	BOONE	Added Travel Lanes	2.01	0.89 mile north of I-465 to 0.65 mile north of SR 334 (Phase 2)
US 50	KNOX	Added Travel Lanes	8.56	0.06 mi W of County Road 600 E to Daviess County Line
US 52	MARION	Added Travel Lanes	1.25	I-465 to Post Rd
US 52	MARION	Added Travel Lanes	3.10	1.33 miles east of I-465 to Marion / Hancock County Line
US 52	HANCOCK	Added Travel Lanes	3.12	Marion / Hancock County Line to CR 500W
US 6	NOBLE	Added Travel Lanes	1.08	West jct with SR 3 to the east jct with SR 3
US 6	PORTER	Added Travel Lanes	3.25	0.4 mile east of SR 51 to Scottsdale Rd, 2.4 miles west of SR 149
US 6	PORTER	Added Travel Lanes	2.44	Scottsdale Rd, 2.44 mile west of SR 149 to SR 149
US 6	PORTER	Added Travel Lanes	1.00	McCool Rd to SR 149
US 6	PORTER	Added Travel Lanes	3.15	Union St to 0.37 mi W of Airport Rd

Appendix B: Details on User Benefit Calculations

The Long Range Plan investments are expected to result in cost savings for users of the state highway system in the form of:

1. Travel time savings;
2. Vehicle operating costs; and
3. Accident cost savings.

The methodologies and assumptions used to calculate each of these concepts are explained in more detail in the following sections. Results of the calculations are summarized in Section 3.0.

Travel Time Savings

Reductions in travel times for motorists and commercial vehicles is the largest source of benefits of the Long Range Plan. Travel time savings (sometimes referred to as "mobility benefits") is the result of time savings provided by the transportation improvements. These savings are achieved directly by faster speeds on improved facilities and reduced distances provided by new facilities. Savings are also provided indirectly by the diversion of traffic away from congested roads to new or improved roads, which allows faster speeds on otherwise unimproved roads.

Indirect travel time savings are also provided by the ability to travel a greater distance within a relatively constant travel time budget. This latter component of travel time savings is referred to by the economic term, "consumer surplus". In the context of user benefit cost analysis, consumer surplus refers to the time savings benefits that accrue to the traveling public by virtue of the fact that a highway improvement may permit the ability to drive a longer distance without increasing travel time, thus opening up an array of new destination choices for many types of trips. It is well documented that vehicle-miles of travel (VMT) do increase in relation to increases in highway system mileage and capacity. From a user benefit standpoint, this is a two-edged sword. On the one hand, the increased VMT may drive up total vehicle operating costs and, since there is more traffic, it at least has the potential to dampen the positive safety effects of a project as well as the travel time benefits. On the other hand, "highway-induced travel demand" would not occur at all, if travelers did not freely elect to travel more in response to the highway improvements. This travel time related benefit make the process of valuing "travel time savings" more complex than simply applying a monetary value to the system-wide reduction in vehicle-hours of traffic

(VHT), since consumer surplus associated with induced demand may eliminate any reduction in total VHT.[1]

The method used for calculating this travel time savings benefits includes the following features: (1) matrix based calculations using "congested skim times" (specifically, average daily speeds) and trip tables (i.e., origin-destination matrices); (2) computation of travel times for base year build and no-build conditions and forecast year build and no-build conditions; (3) linear interpolation of intermediate-year values; (4) vehicle type-specific calculations for autos, single-unit trucks, and combination trucks; (5) application of varying unit values of time by type of vehicle and for work-related vs. non-work-related trips; and (6) valuation of consumer surplus (i.e., longer trips in the build condition vs. no-build condition are valued at one-half the standard values of time).

Since people value their time based on the purpose of the trip, the automobile vehicle-hours of travel (VHT) was divided among three auto trip types: work trips, commute trips, and non-work trips. The vehicle-hours of travel in each of these categories were then converted into person-hours of travel (PHT) using average auto occupancy rates for each of the trip types. Table B.1 shows the automobile VHT share, value of time, and vehicle occupancy assumed for each of the trip types.

Table B.1. Value of Time for Automobile Trips (in year 2000 dollars)

	Auto Work Trips	Auto Commute Trips	Other Non-Business Auto Trips
% of Auto VHT	6.1%	26.9%	67.0%
Vehicle Occupancy (passengers/vehicle)	1.20	1.20	2.22
Value of Person Hrs.	$19.11/hour	$12.33/hour	$6.16/hour

Source: Developed from values and methods reported by Highway Economic Requirements System (HERS), 1991, and Transportation Research Circular 477 (Transportation Research Board, 1997).

Similarly, truck VHT was divided between single-unit trucks and heavy-duty combination trucks. Since the value of time for a truck depends on the value of its cargo as well as the value of the driver's time, and since the average vehicle occupancy for trucks is so close to one, the value of time for trucks is given for vehicle-hours rather than person hours. The values for truck time are show in Table B.2.

[1] For a good discussion of modeling and valuation issues associated with consumer surplus, see: "Issues Relating to Use of Travel Models in Benefit Cost Analysis" by Patrick DeCorla-Souza, *Transportation Research Record 1685*.

Table B.2. Value of Time for Truck Trips (in year 2000 dollars)

	Single Unit Trucks	Combination Trucks
% of Truck VHT	25%	75%
Value of Vehicle Hrs.	$23.45/hour	$28.33/hour

Source: Highway Economic Requirements System (HERS), 2000.

Vehicle Operating Costs

The costs of operating a vehicle are influenced by a host of driving conditions as well as the type of vehicle, itself. Individual operating cost values are computed by vehicle type and by type of cost. The types of cost include:

- ❖ Fuel consumption
- ❖ Oil consumption
- ❖ Tire wear
- ❖ Vehicle maintenance
- ❖ Depreciation

These are computed for the following vehicle types:

- ❖ Small autos
- ❖ Medium/large autos
- ❖ 4-tire trucks
- ❖ 6-tire trucks
- ❖ 3+ axle, single unit trucks
- ❖ 3-4 axle combination trucks
- ❖ 5+axle combination trucks

The method used for computing vehicle operating costs incorporates the following features: (1) constant speed operating cost equations from the *Highway Economic Requirements System* (source: *HERS Technical Report* v 3.54, September 2003); (2) excess fuel consumption adjustment curves for acceleration/deceleration cycles based on link flow density; (3) excess operating cost curves due to speed variability (source: *HERS Technical Report* v 3.26, December 2000); (4) computations for both base year build and no-build conditions and forecast year build and no-build conditions, and (5) truck volumes derived from the Indiana Statewide Travel Demand Model's truck traffic assignments assuming a 75%-25% combination-single unit truck split with light vehicle fleet mix based on national data.

The costs for the five components and the excess costs are adjusted to current dollars based on consumer and producer price indices specific to each cost component. Consumer price indices are used for all auto costs, as well as single-unit trucks' fuel and maintenance for both classes of trucks. Producer price indices are used for all the remaining truck cost components.

An important feature of this analysis is the excess fuel consumption adjustment curves for driving cycles based on link flow density (a.k.a. congestion). Ordinarily, benefit cost analysis bases vehicle operating costs on the simplifying assumption that traffic operates at the constant average speed (i.e., without speed fluctuations) associated with each link in the network. In this analysis, excess fuel consumption resulting from frequent accelerations and decelerations associated with the level of traffic congestion on each link has been incorporated. These curves were developed by Bernardin, Lochmueller & Associates, Inc. (BLA) and incorporated into the latest version of NET_BC. They are based on EPA fuel consumption rates for highway and city driving and calibrated to replicate actual flow conditions as output by the Indiana Statewide Travel Model.

The new method of estimating the vehicle operating costs due to speed variability associated with congestion implemented in this analysis used flow densities from the travel model as the basis for estimating these costs. Traffic flow density was selected as the independent variable based on the inference that speed variability (not associated with traffic control devices) is a function of the stability (or variability) of the traffic flow and that the stability of flows is closely related to their density. A relationship between flow density and light vehicle fuel consumption was developed using available data, and the relative sensitivity of the other vehicle types and operating cost components was based on the HERS excess cost equations. These equations were used to pivot costs for other vehicle types and cost components off of the light vehicle fuel consumption.

Fuel consumption for light vehicles on urban and rural facilities in Indiana was calculated using the applicable HERS average speed equations using the speeds from the model and the model's VMT adjusted by functional class to agree with Highway Performance Monitoring System (HPMS) estimate. To this was added the costs associated with stops at traffic signals. The average urban, rural, and overall consumption rates predicted by the HERS equations were then compared to U.S. Environmental Protection Agency official average fuel consumption rates for light vehicles on urban and rural roadways and the difference was related to the average urban and rural flow densities. A curve was fit to these data and then applied to the Indiana statewide model in a link-by-link calculation. The results are shown below in Table B.3. A remaining additional increment of fuel consumption not accounted for by flow density is presumably due to speed variability associated with turning movements.

Table B.3. Light Vehicle Fuel Consumption (Gallons per 1,000 Miles) and Flow Density (Passenger Car Equivalents per Lane-Mile) in Indiana by Area Type

	Average Flow Density	US EPA National Fuel Consumption	HERS Average Speed Fuel Consumption	HERS + Stops + Excess Consumption using Flow Density
Urban	24.56	53.27	27.78	45.65
Rural	6.71	40.65	36.81	40.09
All	15.87	46.68*	32.17	42.95

Source: Bernardin, Lochmueller & Associates, Inc. The EPA consumption rates were computed from EPA's *light Duty Automotive and Fuel Economy Trends: 1975 through 2003,* Appendix C using EPA's MOBILE6 air quality model's default national fleet composition for the base year 2000. Other fuel consumption rates computed by post-processing the ISTDM.

* The EPA fuel consumption rate for all travel reflects the urban/rural traffic split for Indiana, rather than the nation as a whole.

In addition to the excess costs associated with traffic congestion, traffic signals represent another factor that influences total vehicle operating costs. If a vehicle makes a partial or complete stop at a traffic signal, the "stop-and-go" process will lead to higher operating costs than the costs that are incurred in a constant-speed driving condition without any interruptions by traffic signals. This analysis takes into consideration this impact by adding a sixth cost item in addition to the five mileage-based costs. This additional cost due to traffic control devices is referred to as "excess cost." Table B.4 shows the excess costs associated with coming to a complete stop and reaccelerating, based on initial operating speed and vehicle type.

To estimate excess cost due to signalization, the probability that a vehicle stops at a traffic signal was calculated by using a binomial distribution. The probability of stopping was calculated for different numbers of traffic signals on a link. (Multiple signals can occur in cities/towns at intersections where the cross-road is not a state highway and not included in the ISTDM network.) Based on this probability, total numbers of vehicles that stop at the traffic signal were estimated for each link with one or more traffic signals. Then, excess costs for each of the three vehicle types were estimated, taking into account both the deceleration-acceleration cycle based on the vehicle's initial approach speed as well as the idling time. The costs of idling are shown in Table B.5 and are based on the assumption of an average 45-second stop.

Table B.4. Excess Cost Associated with Stopping and Reaccelerating

	Vehicle Type		
Initial Speed (mph)	**4-KIP Passenger Cars**	**12-KIP Single-Unit Trucks**	**54-KIP 3-S2 Diesel Trucks**
5	$0.83	$3.39	$7.52
10	$2.54	$6.55	$21.04
15	$5.10	$11.62	$37.15
20	$7.74	$17.53	$57.80
25	$11.25	$26.50	$91.04
30	$14.50	$34.82	$113.53
35	$17.75	$43.88	$151.47
40	$21.00	$48.47	$163.99
45	$24.25	$56.22	$197.84
50	$27.50	$61.86	$223.98
55	$30.75	$66.48	$240.68
60	$34.04	$71.31	$262.71
65	$37.45	$80.72*	$290.93*
70	$40.90	$87.38*	$315.57*

Source: *A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements*, American Association of State Highway and Transportation Officials, 1977.
* Values extrapolated by linear regression.

Table B.5. Excess Cost Associated with Idling While Stopped (2002$)

Passenger Car	Single Unit Truck	Combination Truck
$0.0106	$0.0163	$0.0169

Source: *A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements Table B-10 through B-12* and NCHRP Report 136.

Another feature of the analysis is the incorporation of topographical impacts on vehicle operating costs. Operating costs vary depending on the vertical grade of the road with the impact being more severe for trucks. Approximate grades were estimated by county and functional class of the roadway. Although the use of grades in the estimation of vehicle operating costs has long been a part of the HERS model applied to individual roadway segments, the incorporation of estimated grades on a system-wide basis represents a significant advance over earlier analyses that lacked them. Table B.6 shows the percentage differences in total operating costs for varying grades as compared to costs on level terrain. Values from this table were incorporated into the analysis.

Table B.6. Percentage Difference in Vehicle Operating Costs on Grades

Speed (mph)	Grade (%)								
	-4	-3	-2	-1	0	1	2	3	4
5	88.72%	88.70%	92.02%	94.40%	100.00%	108.38%	122.49%	130.98%	154.72%
10	85.60%	86.46%	86.24%	93.39%	100.00%	114.07%	126.05%	139.17%	157.31%
15	82.38%	84.67%	86.94%	92.79%	100.00%	119.79%	129.57%	147.68%	158.47%
20	79.02%	80.88%	82.17%	91.53%	100.00%	119.51%	133.13%	152.84%	171.35%
25	75.75%	78.56%	82.04%	90.05%	100.00%	120.76%	134.39%	153.05%	174.30%
30	73.43%	76.93%	80.85%	89.71%	100.00%	120.26%	135.07%	155.15%	177.85%
35	71.33%	75.58%	79.61%	89.89%	100.00%	118.88%	135.46%	156.92%	182.52%
40	70.80%	74.75%	82.25%	91.58%	100.00%	118.85%	137.24%	159.45%	192.17%
45	70.36%	74.97%	80.52%	91.15%	100.00%	118.34%	137.91%	161.47%	n/a
50	n/a	69.73%	82.61%	92.48%	100.00%	118.68%	137.88%	n/a	n/a
55	n/a	76.33%	83.08%	92.95%	100.00%	119.00%	n/a	n/a	n/a
60	n/a	N/a	83.71%	91.87%	100.00%	116.82%	n/a	n/a	n/a

Source: *A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements*, American Association of State Highway and Transportation Officials, 1977.

Accident Cost Savings

User benefits associated with expected crash reductions attributable to the build-out of the Long Range Plan were estimated by computing the probable number and type of crashes that would occur if the Plan were implemented versus the number and type of crashes assuming the status quo. The number and type of crashes were computed based on area type, daily traffic volume range on each link in the network, and facility type. Average cost factors associated with each type of accident were then applied to the "build" versus "no-build" conditions. The difference between the total accident costs with and without the planned improvements represents the safety benefits of the Plan. The accident cost factors used in the analysis are shown in Table B.7.

Table B.7. Accident Costs by Accident Type

Accident Type	Fatal	Personal Injury	PDO
Unit Cost per Crash	$3,763,418	$82,359	$4,266

Source: USDOT, NHTSA, The Economic Impact of Motor Vehicle Crashes, May 2002.

The crash rates used in this analysis were taken from Tables A-37 through A-39 in *Microcomputer Evaluation of Highway User Benefits* (Texas Transportation Institute, NCHRP 7-12, October, 1993). The source of the accident rates in these tables was The Highway Economic Requirements System (HERS) (developed by Jack Faucett Associates for FHWA, USDOT, July, 1991). Individual crash rates were applied for each of the three major classifications of accidents: fatalities, injuries, and property damage only (PDO). Crash rates, displayed in Tables A.8.a, A.8.b, and A.8.c, are presented per million vehicle-miles of travel by facility type and by average daily traffic volume range.

Table B.8.a Accident Rate per Million Vehicle Miles of Travel for Fatal Accidents by Facility Type and Daily Traffic Volume Range

Crash Type	Area Type	Facility Type	Daily Traffic Volume Range 0-2k	2-4k	4-8k	8-16k	16-24k	24-36k	36-58k	58-76k	76k+
Fatal	Rural	Interstate	0.0158	0.0158	0.0158	0.0119	0.0119	0.0119	0.0119	0.0119	0.0119
		Princ. Arterial	0.0198	0.0198	0.0198	0.0158	0.0158	0.0198	0.0198	0.0198	0.0198
		Min artrl/maj col	0.0400	0.0400	0.0400	0.0240	0.0240	0.0240	0.0240	0.0240	0.0240
		Min coll/local	0.0400	0.0400	0.0400	0.0280	0.0280	0.0280	0.0280	0.0280	0.0280
	Urban	Interstate	0.0140	0.0140	0.0140	0.0140	0.0120	0.0100	0.0100	0.0100	0.0100
		Princ. Arterial	0.0220	0.0220	0.0220	0.0200	0.0180	0.0160	0.0160	0.0160	0.0160
		Min artrl/maj col	0.0450	0.0473	0.0315	0.0270	0.0203	0.0180	0.0180	0.0180	0.0180
		Min coll/local	0.0225	0.0360	0.0270	0.0225	0.0180	0.0180	0.0180	0.0180	0.0180

Source: *Highway Economic Requirements System* (HERS), 1991.

Table B.8.b. Accident Rate per Million Vehicle Miles of Travel for Injury Accidents by Facility Type and Daily Traffic Volume Range

Crash Type	Area Type	Facility Type	Daily Traffic Volume Range 0-2k	2-4k	4-8k	8-16k	16-24k	24-36k	36-58k	58-76k	76k+
Injury	Rural	Interstate	0.2430	0.2430	0.2430	0.2430	0.2430	0.2430	0.2430	0.2430	0.2430
		Princ. Arterial	0.6480	0.6480	0.6480	0.6480	0.8100	0.8100	0.8100	0.8100	0.8100
		Min artrl/maj col	0.8250	0.8800	1.0040	1.1010	1.1690	1.1690	1.1690	1.1690	1.1690
		Min coll/local	0.8250	0.8250	0.9080	1.0730	1.0730	1.0730	1.0730	1.0730	1.0730
	Urban	Interstate	0.3310	0.3310	0.3160	0.3160	0.3310	0.2510	0.3310	0.3630	0.4090
		Princ. Arterial	1.7330	1.7330	1.7330	1.7800	1.8430	1.4020	1.4020	1.4020	1.4020
		Min artrl/maj col	2.5190	2.5190	2.0640	2.2590	2.4710	2.3730	2.3730	2.3730	2.3730
		Min coll/local	1.2680	1.2680	1.7550	2.1450	2.5680	2.5680	2.5680	2.5680	2.5680

Source: *Highway Economic Requirements System* (HERS), 1991.

Table B.8.c. Accident Rate per Million Vehicle Miles of Travel for Property Damage Only (PDO) Accidents by Facility Type and Daily Traffic Volume Range

Crash Type	Area Type	Facility Type	Daily Traffic Volume Range								
			0-2k	2-4k	4-8k	8-16k	16-24k	24-36k	36-58k	58-76k	76k+
PDO	Rural	Interstate	0.3900	0.3900	0.3900	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000
		Princ. Arterial	0.6300	0.6300	0.6300	0.6400	0.6700	0.6700	0.6700	0.6700	0.6700
		Min artrl/maj col	0.8900	0.9800	1.0600	1.1500	1.0100	1.0100	1.0100	1.0100	1.0100
		Min coll/local	0.9900	0.9900	1.0000	1.3000	1.3000	1.3000	1.3000	1.3000	1.3000
	Urban	Interstate	0.7050	0.7050	0.6950	0.6950	0.6100	0.5900	0.7050	0.8250	0.8800
		Princ. Arterial	2.1950	2.1950	2.1950	2.2750	2.4650	2.3350	2.3350	2.3350	2.3350
		Min artrl/maj col	2.8360	2.8330	3.2970	3.6430	4.0533	3.8033	3.8033	3.8033	3.8033
		Min coll/local	2.1600	2.1500	3.1200	3.7300	4.0100	4.0100	4.0100	4.0100	4.0100

Source: *Highway Economic Requirements System* (HERS), 1991.